# A study on effect of interaural phase difference on perception of alarm signals in noisy environments

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February 9, 2006

**Keywords:** alarm signal, masking effect, SRM, ITD, IPD.

## 1 Introduction

Alarm signals should be perceived accurately and efficiently even in real environments to know what does event occur. However, some interference such as masking effects by noise is occurred in noisy environments so that perception of the alarm signal is disturbed. This is a serious problem because this causes many dangerous situations for persons who should hear alarm signals. Therefore, it is important to present alarm signals for them to be accurately perceived in any environments.

There is a phenomenon that the masked threshold can be improved by using spatial cue in binaural hearing when the signal and noise are spatially separated. This is referred as "spatial release from masking (SRM)". If SRM is occurred in real environments, it can be contributed to make the alarm signal to which the influence by noise is suppressed and perceived their existence and directions easily.

In this study, in order to demonstrate effect of interaural phase difference (IPD) on perception of alarm signals in noisy environments, masked thresholds of binaural alarm signals in noise were measured as a function of interaural time difference (ITD) by alarm signals changed the frequency of the components.

## 2 Design of experiments

In general, alarm signals are used in real environments. Therefore, experiments should be carried out in real environments. However, it is difficult to explore the influence of the reverberation and the back ground noise etc. in the perceptual characteristics, separately. Then, for the reason that SRM is depended on ITD and interaural level difference (ILD), in order to explore the influence of ITD and ILD in SRM, separately, experiments were carried out in the sound proof room with a headphone.

First, in order to explore the perceptual characteristics when only ITD was given as a cue, masked thresholds were measured as a function of ITD by the click signal. Second, in order to explore the perceptual characteristics when ITD and IPD were given as cues, masked thresholds were measured as a function of ITD by alarm signals.

## 3 Experiment I: ITD cue

### 3.1 Purpose

Purposes of this experiment are shown as follows. First, the importance of ITD is shown. Second, it is described whether to show the tendency that is similar to the tendency obtained when the stimulus was presented in the free sound field.

### 3.2 Procedure

Only ITD was set to signals. When the median plane was assumed to be 0°, the signal source was moved at the right of the subject (15°, 30°, 45°, 60°, 75° and 90°). The signal - noise configurations were described as follows. The condition that both the signal and the noise located at 0° is denoted by $S_0N_0$. Signal at 15° and noise at 0° ($S_{15}N_0$) and so on.

### 3.3 Results

As the signal was moved at the right of the subject, masked thresholds were decreased. This result is similar to the tendency obtained when the

stimulus was presented in the free sound field. When the stimulus was presented in the free sound field, masked thresholds were decreased about 15 dB in the condition of $S_{90}N_0$. In this experiment, masked thresholds were decreased 7.6 dB when ITD was changed only. Therefore, it was shown that SRM was occurred by only ITD. In addition, the importance of ITD was shown for the reason that large release from masking of 7.6 dB was occurred by changing only ITD.

# 4 Experiment II: ITD and IPD cues

## 4.1 Purpose

In this experiment, three alarm signals changed the frequency of the components (1.5, 2.0 and 2.5 kHz) were used as signals. Alarm signals are set ITD and operated the direction. However, in this case, it is thought that the situation in which IPD can be used as cue at other than ITD is given to the subject. Then, in order to explore the perceptual characteristics when ITD and IPD were given as cues, masked thresholds of alarm signals in noise were measured as a function of ITD by alarm signals. In addition, it is assumed that the frequency of about 2 kHz is good as for the component frequency of the alarm signal. However, it is generally known that localization ability using ITD for a pure tone is reduced in case that the component frequency of pure tone is about 1.5 kHz, and the localization is used IPD when the frequency is 1.5 kHz or less and ILD when the frequency is 1.8 kHz or more as the main cue. It is considered whether to occur SRM under such a situation.

## 4.2 Procedure

Procedure were the same as in Sec. 3.

## 4.3 Results

In the case that the frequency of the component is 1.5 kHz, the masked threshold was decreased 2.3 dB at the maximum in the $S_{45}N_0$ condition. The masked threshold at the $S_{90}N_0$ condition showed the masked threshold

similar to the $S_0N_0$ condition. This result can be explained by binaural masking level difference (BMLD). Where the component frequency of the alarm signal is 1.5 kHz and the sampling frequency is 48 kHz. Therefore, time per one period of sine wave of frequency 1.5 kHz is about 0.67 ms. This time is the same that ITD is occurred at the $S_{90}N_0$ condition. In other words, in the $S_{90}N_0$ condition, the alarm signal is presented at the condition that one period was just shifted between both ears. Therefore, it is thought that a high threshold was obtained because it became extremely near to the condition that the homophasic alarm signal is presented between both ears. Similarly, in the $S_{45}N_0$ condition, it is thought that a low threshold was obtained because the phase of the alarm signal was shifted half period between both ears. In the case that the frequency of the component is 2.0 and 2.5 kHz, they were also showed similar. In the case that the frequency of the component is 2.0 kHz, a high threshold was obtained because the alarm signal became homophasic between both ears in the $S_{60}N_0$ condition, and a low threshold was obtained because the alarm signal became antiphasic between both ears in the $S_{30}N_0$ condition. In the case that the frequency of the component is 2.5 kHz, a high threshold was obtained because the alarm signal became homophasic between both ears in the $S_{45}N_0$ condition, and a low threshold was obtained because the alarm signal became antiphasic between both ears in the $S_{15}N_0$ condition and the $S_{75}N_0$ condition.

# 5 Conclusion

In this study, two experiments were carried out using the click signal and three alarm signals to explore the perceptual characteristics for alarm signals. As the results, it was shown that SRM was occurred when using only ITD. Therefore, the importance of ITD was shown for the reason that large release from masking was occurred by changing only ITD. In addition, results showed that the perception of the alarm signal is influenced not only ITD but also IPD of the signal, depended on the frequency of the components of the signal. This suggests that the frequency of the alarm signal and ITD and IPD at the frequency have to be considered to convey warning accurately and efficiently without loss of information.